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Evaluation of Fuzzy Logic Control Technique for DC Motor Drives Using MAT LAB/SIMULINK

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***Abstract*— High efficiency due to reduced losses, low maintenance and low rotor inertia of the dc motor have increased the demand of DC motors in high power servo and robotic applications. With the advent of controllers like fuzzy logic, which can convert linguistics control variables based on expert knowledge or practical results into desired control strategies. So it can be applied for various control system with uncurtained and unmodelled dynamics. This paper proposes three types of fuzzy logic controllers for DC motor drive using Mat lab/Simulink and presents a comparative study of performance specifications of PI and PID controllers and three fuzzy logic. The steady and dynamic characteristic of speed and torque are effectively monitored and analysed. The aim of fuzzy logic controllers is to obtain improved performance in terms of disturbance rejection or parameter variation than obtained using classical controllers. The fuzzy self-tuning approach implemented on a conventional PID structure was able to improve the dynamic as well as the static response of the system. Comparison between the conventional output and the fuzzy self-tuning output was done on the basis of the simulation result obtained by MATLAB. The simulation results demonstrate that the designed self-tuned PID controller realize a good dynamic behaviour of the DC motor, a perfect speed tracking with less rise and settling time, minimum overshoot, minimum steady state error and give better performance compared to conventional PID controller.**

***Index Terms*— DC motor, HFLC, IFLC, Mat lab, PID.**

I. INTRODUCTION

The dc motor have immense demand in high power servo and robotic applications. A promising direction in the design of intelligent control systems involves the use of Fuzzy logic controller to discover the abilities of intelligent control systems in utilizing experience via rule-based knowledge. DC motor as the name indicates is a motor initiated usually by direct current and is converted into mechanical energy according to the requirement.

DC motors are generally classified into two types:

1) Self-excited DC motor.
2) Separately excited DC motor.

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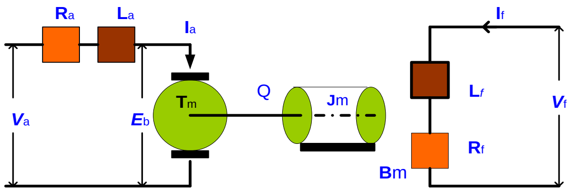

Fig.1: Separately excited DC motor model.

Our research work aims at speed controlling of separately excited DC motor. The major reason of working on

separately excited DC motor is that initiation of the motor is independent of internal circuitry of the machine. In separately excited DC motor, speed can be controlled by following methods:

1) By controlling Armature voltage of the machine;
2) By adding variable resistance to armature circuit resistance.

Research studies have been done on using different controllers to control speed of separately excited DC motor. Several mathematical models have been used to control speed of drive as discussed in. Different types of controllers used are Proportional Integral Controller (PI), Proportional Integral Derivative Controller (PID) etc. Our research work has aimed on achieving precise and accurate speed control of separately excited DC motor by using Fuzzy Controller. The purpose is to provide a better speed control method by comparative study of conventional and fuzzy controllers**.**

II. MATHEMATICAL MODELLING OF DC MOTOR

Mathematical Model of dc motor can be presented either by keeping field parameter constant and varying the armature parameters –armature control or by keeping armature parameters constant and varying the field parameter- field control. Thus two technique for Speed control in dc motor are:

1) Armature Control
2) Field Control

A. Armature Control

Figure shows a separately excited DC motor equivalent model

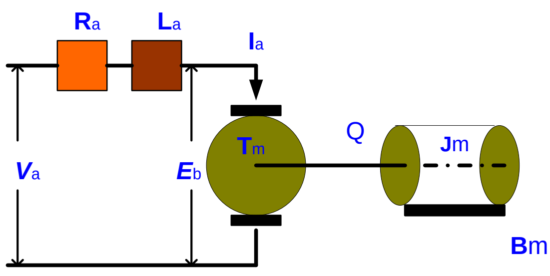

Fig. 2: Separately Excited Dc Motor

$$V_a(t) = I_a R_a(t) + L_a \frac{dI_{a(t)}}{dt} + e_b(t) \quad (1)$$
$$e_b(t) = K_b w(t) \quad (2)$$
$$T_m(t) = K_t I_a(t) \quad (3)$$
$$T_{m\,(t)} = J_m . \frac{dw(t)}{dt} + B_m . w(t) \quad (4)$$
$$V_a(t) = I_a R_a(t) + L_a \frac{dI_{a(t)}}{dt} + K_b w(t) \quad (5)$$

$$K_T I_a(t) = J_m \frac{dw(t)}{dt} + B_m . w(t) \quad (6)$$

Let us combine the upper equations together

Taking Laplace Transform of (5) & (6)

$$V_a(S) = R_a I_a(s) + L_a I_a(s) + K_b W(s) \quad (7)$$

$$K_T I_a(s) = J_m W(s) + B_m W(s) \quad (8)$$

If current is obtained from (8) and substituted in (7) we have…

$$V_a(s) = W(s) \frac{1}{K_t} [L_a I_m s^2 + (R_a I_m + L_a B_m(s) + (R_a B_m + K_b K_t)]$$

Then the relation between rotor shaft speed and applied armature voltage is represented by transfer function:

$$\frac{W(s)}{V_a(s)} = \frac{K_t}{[L_a J_m s^2 + (R_a J_m + L_a B_m)s + (R_a B_m + K_b K_T)]}$$

The relation between position and speed is:

$$\theta(s) = \frac{1}{s} . w(s)$$

Then the transfers function between shaft position and armature voltage at no-load is:

$$\frac{\theta(s)}{V_a(s)} = \frac{K_t}{[L_a J_m s^3 + (R_a J_m + L_a B_m)s^{2c} + (R_a B_m + K_b K_T)s]}$$

III. CONVENTIONAL CONTROLLERS

A. Proportional Plus - Integral (PI) Controller

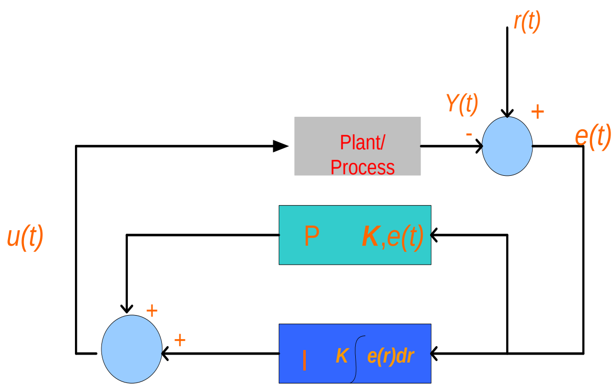

Fig. 3: Block Model of PI Controller

Under PI Controller as long as error is present the controller keeps changing its output and once the error is zero or it disappears the controller does not change its output. The output of the controller is changed proportional to the integral of the error.

The mathematical expression of the PI Controller is:

$$y = K_p . e + Ki \int e . dt$$

Where, Ki = Integral gain of the PI controller.

Disadvantages of PI Controller is: The response is sluggish at the high value of the integral time. The control loop may oscillate at the small value of integral time.

B. Proportional-Integral-Derivative (PID) Controller

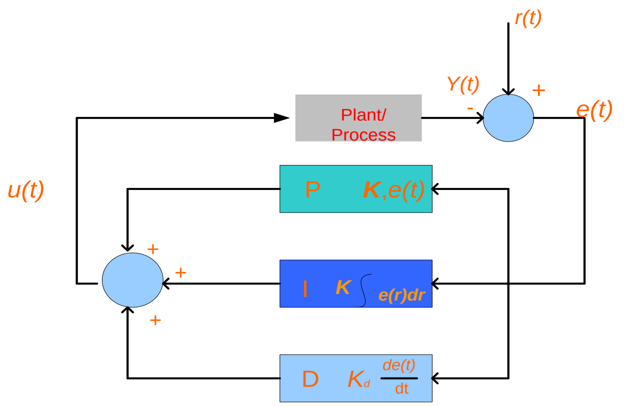

Fig. 4: PID Controller Block Diagram

PID controller calculates an "error" value as the difference between a measured process variable and a desired set point. Controller attempts to minimize the error by adjusting the process control inputs. The PID controller calculation (algorithm) involves three separate control units. Accordingly sometimes called three-term control: the proportional, the integral and derivative values, denoted *P*, *I*, and *D*. The influence of the three components can usually be set externally. Each of the three components covers one of the controller's tasks. The output of the controller or the manipulated variables is obtained by adding P, I, D, components and their associated coefficients. The mathematical expression of the PID Controller is:

$$y = K_p . e + K_i \int e . dt + K_0 . \frac{de}{dt}$$

IV. FUZZY LOGIC CONTROLLER

Fuzzy logic control is a control algorithm based on a linguistic control strategy, which is derived from expert knowledge into an automatic control strategy. The operation of a FLC is based on qualitative knowledge about the system being controlled .It doesn't need any difficult mathematical calculation like the others control system. While the others control system use difficult mathematical calculation to provide a model of the controlled plant, it only uses simple mathematical calculation to simulate the expert knowledge

A fuzzy logic controller has four main components as shown in Figure:

a) Fuzzification
b) Inference engine
c) Rule base
d) Defuzzification

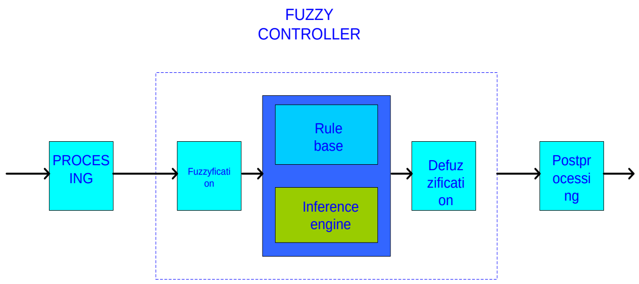

Fig. 5: Structure of fuzzy logic controller

A. Fuzzification

The first step in designing a fuzzy controller is to decide which state variables represent the system dynamic performance must be taken as the input signal to the controller. Fuzzy logic uses linguistic variables instead of numerical variables. The process of converting a numerical variable (real number or crisp variables) into a linguistic variable (fuzzy number) is called fuzzification. This is achieved with the different types of fuzzifiers.

B. Rule base

A decision making logic which is, simulating a human decision process, inters fuzzy control action from the knowledge of the control rules and linguistic variable definitions. The rules are in “If Then” format and formally the If side is called the conditions and the Then side is called the conclusion. The computer is able to execute the rules and compute a control signal depending on the measured inputs error € and change in error (de). In a rule based controller the control strategy is stored in a more or less natural language. A rule base controller is easy to understand and easy to maintain for a non- specialist end user and an equivalent controller could be implemented using conventional techniques.

V. SIMULATION MODEL AND ITS RESULT

A. Model for Armature Control of Dc Motor

i) Simulation Result of Armature Control

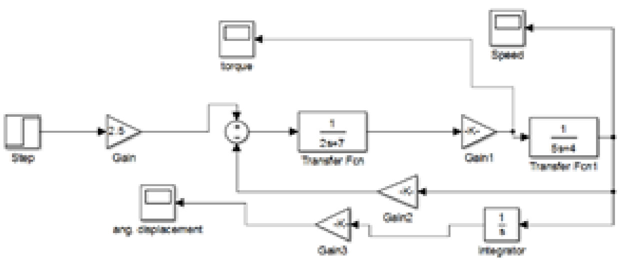

Fig. 6: Model for Armature Control

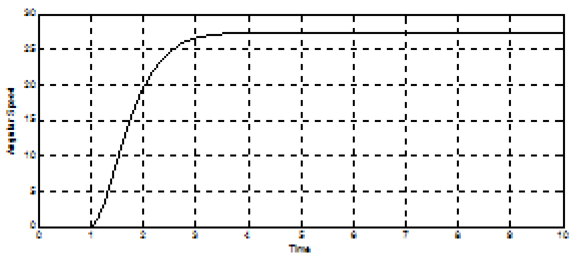

Fig. 7: Angular Speed- Armature control

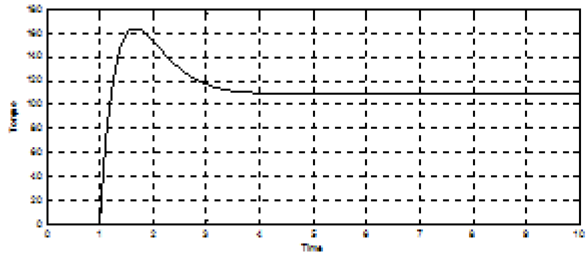

Fig. 8: Torque- Armature control

B. Simulink Model for Field Control of Dc Motor

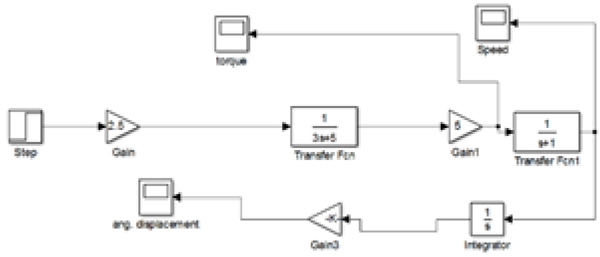

Fig. 9: Model for Field Control

i) Simulation Result of Field Control

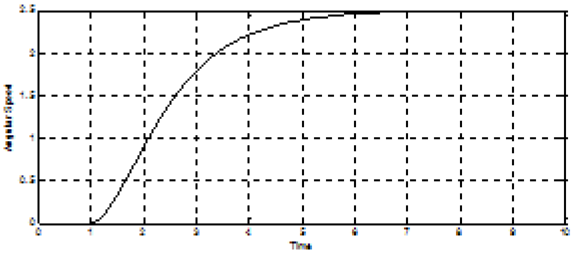

Fig. 10: Angular Speed- Field Control

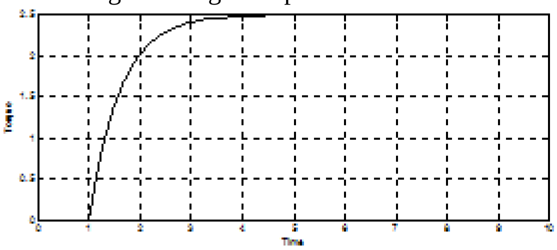

Fig. 11: Torque- Field Control

C. Comparision Of Armature Control With and Without Pid Controller

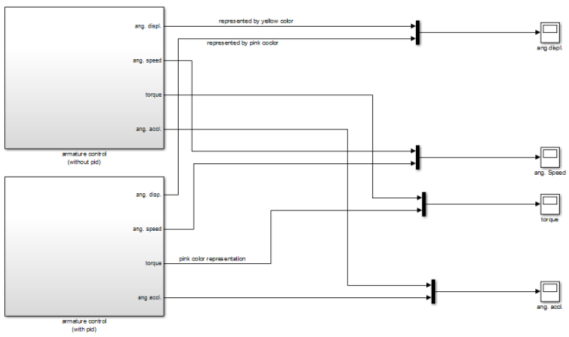

Fig. 12: Model for armature control with and without pid controller

i) Simulation Result of Armature Control With & Without Pid

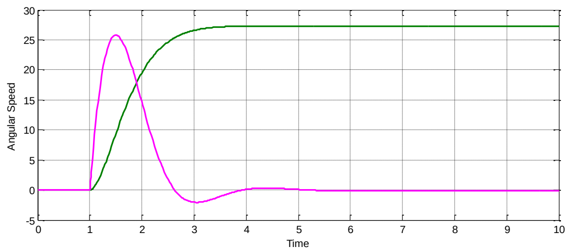

Fig. 13: Angular Speed for armature control with and without pid controller

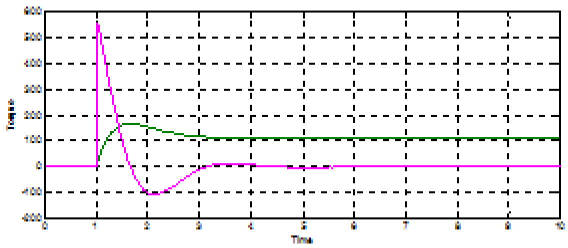

Fig. 14: Torque for armature control with and without pid controller

D. Armature Control Using Fuzzy Logic

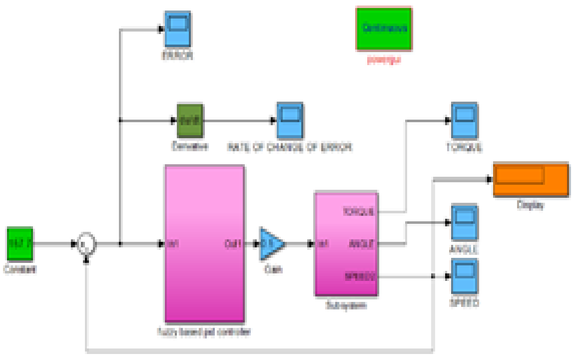

Fig. 15: Model of Armature Control using Fuzzy Logic.

i) Simulation Result for Armature Control Using Fuzzy Logic

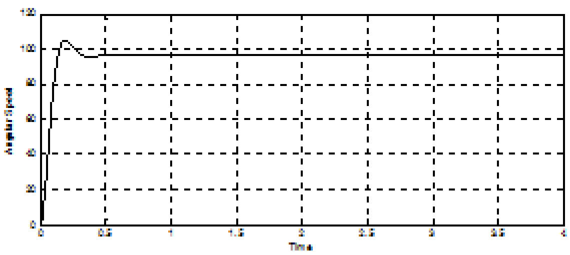

Fig. 16: Angular Speed for Armature Control using Fuzzy Logic.

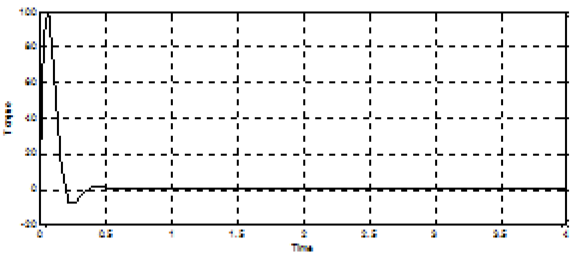

Fig. 17: Torque for Armature Control using Fuzzy Logic.

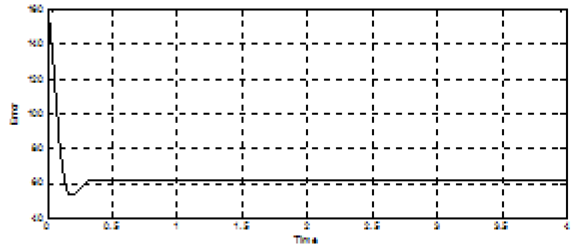

Fig. 18: Error for Armature Control using Fuzzy Logic.

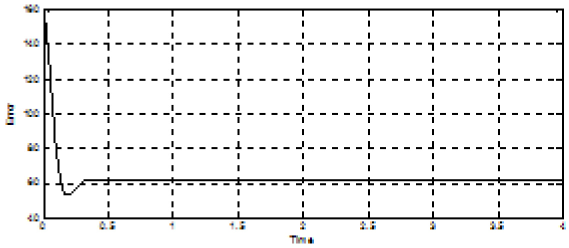

Fig. 19: Change in Error for Armature Control using Fuzzy Logic.

VI. CONCLUSION

By considering all the aspect it can be concluded that speed in dc motor can be regulated widely through various controllers. Also different models of dc motor has varying speed, torque characteristic. In this paper we first studied the field control and armature control model of dc motor. It came into consideration that armature control model has better speed regulation as compared to field control. This is due to the fact that flux can only be decreased in dc motor so speed can be changed in small limit. Use of conventional controller like PI controller, PID controller for speed control give better result. Moreover by using PID controller the transient as well as steady state response improves when a step input is given to field controlled motor, a large time constant (11sec) is obtained, shows a sluggish system and in case of Armature controlled motor, a small time constant (6 sec) is obtained corresponds to a fast response. The introduction of fuzzy logic inference system to regulate the three parameters of a PID controller displayed better performance by reducing steady state error, maximum overshoot, rise time and settling time. FLC have more sensitive responses against load disturbances to classical PI & PID controller. FLC is better than conventional PI & PID controller.

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